Thermally Stable Ge/Cu/Ti Ohmic Contacts to n-type GaN

NADEEMULLAH MAHADIK,[1] MULPURI V. RAO,[1,3] and ALBERT V. DAVYDOV[2]

1.—Department of Electrical and Computer Engineering, George Mason University, Fairfax, VA 22030.
2.— Materials Science and Engineering Laboratory, National Institute of Sciences and Technology, Gaithersburg, MD 20899. 3.—E-mail: rmulpuri@gmu.edu

The performance of a novel Ge/Cu/Ti metallization scheme on n-type GaN has been investigated for obtaining thermally and electrically stable low-resistance ohmic contacts. Isochronal (2 min.) anneals in the 600–740°C temperature range and isothermal (690°C) anneals for 2–10 min. duration were performed in inert atmosphere. For the 690°C isothermal schedule, ohmic behavior was observed after annealing for 3 min. or longer with a lowest contact resistivity of 9.1×10^{-5} Ω cm^2 after the 10 min. anneal for a net donor doping concentration of 9.2×10^{17} cm^{-3}. Mean roughness (R_a) for anneals at 690°C was almost constant at around 5 nm, up to an annealing duration of 10 min., which indicates a good thermal stability of the contact scheme.

Key words: Ohmic contacts, GaN, metallization

INTRODUCTION

Gallium nitride is the subject of extensive research for making commercial ultraviolet (UV)-blue light sources,[1,2] high-power microwave devices,[3] and high-temperature electronics.[4] Realization of low-resistivity (ρ_c), thermally stable ohmic contacts is vital for high performance device applications.[5] Because the Fermi level on the GaN surface is unpinned,[6] ohmic contacts for n-type GaN can be formed by selecting a metal whose work function is less than the electron affinity of GaN, or by increasing donor concentration at the GaN surface to invoke tunneling. There are numerous reports[7–26] on developing and optimizing ohmic contacts to n-type GaN. Traditionally, contact schemes with titanium metal as the first layer have been most widely used.[8–11,15,22] Ti is selected as the first contact layer to n-type GaN because its work function, 4.33 eV, is close to that of n-GaN (electron affinity = 4.1 eV). Ohmic behavior of a GaN/Ti system has been attributed to the out-diffusion of nitrogen from the GaN into the Ti, creating N vacancies, which act as donors at the GaN surface.[8,10,11,22] The introduction of excess donors at the metal/n-GaN interface causes carrier tunneling through the thin metal/semiconductor barrier, which results in an ohmic behavior to the contact system. Ti is also known to reduce native oxide on the GaN surface, thus promoting more intimate metal-to-GaN contact. Hence, a Ti layer at the metal-contact/GaN interface has proved beneficial and is currently used in most of the contact schemes.

In this work, we investigated the Cu-based scheme as an alternative to commonly used Au, Al-containing metallization (e.g., Au/Al/Ti) for forming ohmic contacts to n-GaN. To our knowledge, there has been only one report[24] on copper-based ohmic contacts to n-type GaN, with annealing performed at 400°C for a prolonged time, and one report[25] on forming Cu_3Ge-based Schottky contact to n-type GaN at a much higher annealing temperature. This ambiguity in metallization composition, annealing temperature, and time needs to be investigated. Also, there have been a few reports[26,27] on copper-based ohmic contacts to p-type GaN. If Cu-based low-resistivity contacts can also be developed for n-type GaN, then ohmic contacts to both n- and p-type regions in GaN-based device structures can be formed concurrently in the same process. Because the work function of copper is greater than the electron affinity of GaN (4.65 eV and 4.1 eV, respectively), Cu should not produce an ohmic contact due to the barrier at the Cu/n-GaN interface. To create ohmic contacts to n-GaN, a metal with a lower work function, such as Ti, needs to be used as the first layer. Germanium, which is predominantly a donor impurity in III-V compounds, can be added to the ohmic contact metal system to invoke tunneling at the metal/n-GaN contact. In this work, we have selected the Ge/Cu/Ti metal scheme with the thickness of Ge and Cu layers

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